Biodiversity and Conservation **13:** 959–983, 2004.

Biodiversity impact analysis in northwest Yunnan, southwest China

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Received 12 September 2002; accepted in revised form 19 March 2003

Key words: Biodiversity impact assessment, China, Land cover change, Livelihoods, Policy impacts

Abstract. This paper reports the main findings of a study on the factors threatening biodiversity in northwest Yunnan, a global biodiversity 'hotspot' in China and home to over five million people. The research was based on eight site-level case studies. The main driving forces of biodiversity loss are livelihood activities, including agricultural production, livestock grazing and the collection of fuel wood, construction timber and NTFPs. Behind these specific drivers are underlying factors including changes in demography, market conditions, resource tenure policies and development policies and projects. Some change in land cover has been due to specific trigger events, the most significant of which reflect national policy changes. At the site level, a range of biophysical and socio-cultural factors influence the specific outcomes that any particular factor may have. The paper suggests some specific redressive measures and general implications for research and policy.

Introduction

During the last century, biodiversity loss occurred at an unprecedented pace. Biodiversity is a natural attribute of ecosystems and is the product of interactions between social and natural systems (Sajise 1995), and as such, biodiversity has close links with local ecological, economic and socio-cultural functions. Ecological functions include hydrological cycles, food chains, vegetation succession, soil erosion control and climate regulation. Functions related to direct human use include foods, medicines, handicrafts, fuel wood and timber for furniture and house construction. Cultural functions include the creation of symbolic values, regulation of human–spirit interactions, and aesthetic and recreational functions. Biodiversity often has marketing value, which provides a substantial income, particularly for forest-dependent indigenous peoples.

Northwest Yunnan is well known in China for its biological and cultural diversity. The region, covering an area of almost 70 000 km^2, has been designated as a global biodiversity 'hotspot' by WWF/IUCN (Mackinnon et al. 1996). It is also home to over five million people belonging to more than 10 ethnic groups, whose

livelihood strategies vary from hunting and gathering, fishing, transhuman grazing and shifting cultivation to intensive agriculture. Each culture has developed distinct patterns of interaction with the natural environment. Poverty is widespread in NW Yunnan, and rural people face a variety of uncertainties in their livelihoods arising from government policies, migration, development interventions and the expansion of markets. Cultures are changing and many biological resources are vulnerable to depletion.

Given its high conservation value, the region has received attention from many international organizations. Through a system of nature reserves and a more recent ban on logging of natural forests, the government is actively supporting efforts to conserve the region's unique ecological and cultural landscapes, for both the ecological services they render and for the potential they provide for revenues from tourism and bio-resource extraction. As government policy turns towards a conservation orientation, the identification of threats to biodiversity and a correct understanding of the dynamics associated with these threats are essential to the development of appropriate policies and interventions that conserve biodiversity. It is also equally important that these measures promote the development of sustainable livelihoods for local people.

The research reported in this paper aims to understand the driving forces behind the threats to biodiversity in NW Yunnan and to suggest locally relevant interventions to abate these threats, while at the same time supporting the sustainable and equitable livelihoods as well as the cultural identity of local people. We first describe the ecology of the region and the main conservation targets, and the methodology used. Based on eight case studies, we then discuss the main drivers of impacts on biodiversity, underlying factors, and trigger factors. Finally, we present some general recommendations for policy and research.

Biodiversity of NW Yunnan

NW Yunnan lies in the transitional region between the Qinghai-Tibet and the Yunnan-Guizhou Plateaus in the southern extent of the East Himalayas (see Figure 1). The region has unique ecological functions, as it is the upper stream of four major rivers – the Yangtze (Jinsha) River, the Mekong (Lancang) River, the Salween (Nujiang) River and the Irrawaddy (Dulongjiang). These rivers run in parallel courses between narrow mountain ranges, constituting a highly diverse landscape, with distinct vertical distributions of vegetation types. NW Yunnan has been internationally identified as a globally significant region for its rich biodiversity, rare ecosystems and high concentration of endemic biodiversity (Convention on Biological Diversity 2001). Many conservation targets within the region are significant because of their rarity, the ecological services they provide and their role in supporting habitats of rare and endemic species.

The region covers the 15 counties of the Diqing, Lijiang, Nujiang and Dali Prefectures. Table 1 shows that the majority of land cover in NW Yunnan consists of

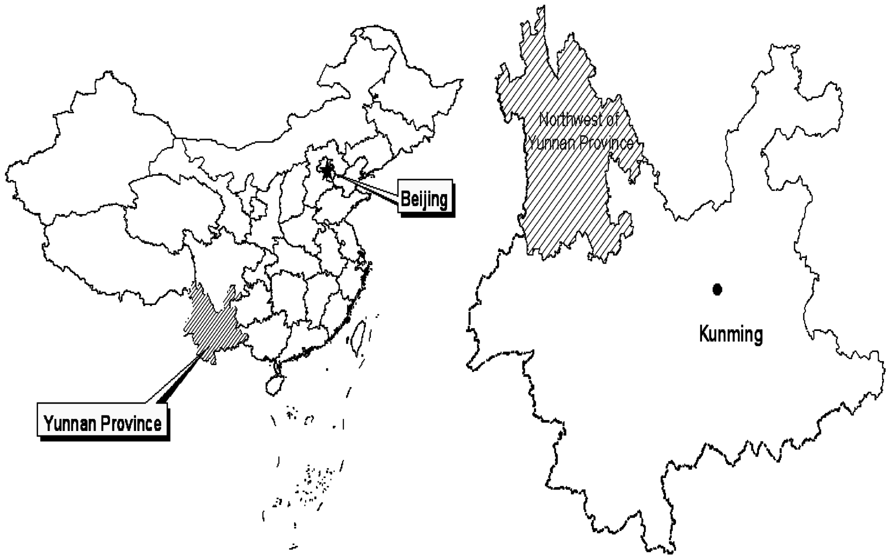

Figure 1. Location of northwest Yunnan, China.

Table 1. Land use and land cover in northwest Yunnan, China.

Land use category	Area (ha)	%
Agricultural land	567 855	8.5
Forest land	4 197 351	63
Grassland	1 600 594	24
Water bodies	78 768	1.2
Urban and residential areas	20 071	0.3
Others	207 346	3
Total	6 671 985	100

Based on 1998 Landsat images; analysis undertaken by Xuefei Yang.

forest and grasslands. A total of 10 vegetation types and 98 formations can be found in the region, many of which have high conservation value, owing to their species richness and fragility. The most important vegetation types in the region are alpine mosaic and a variety of natural forest ecosystems. Over half the land area (6 671 985 ha) is forest cover, of which 98.3% is natural forest. Major forest types include evergreen broadleaf forest and mixed forest. After alpine mosaic, evergreen broadleaf forest has the second highest number of rare and endangered plant species in the region (Guo and Long 1998). Much of its limited distribution area lies outside existing nature reserves. Highland lakes and wetlands provide important habitats for many endemic plant and wildlife species, including migratory birds such as the Black-necked crane (*Grus nigricollis*).

NW Yunnan is one of the three endemic species centers in China (Guo and Long 1998). It is rich in plant diversity with a high degree of endemism (see Table 2),

and is the worldwide center for the distribution of many types of flower, such as the rhododendron and the primrose. NW Yunnan is also home to about 2000 species of medicinal plants. The region has 84 rare or endangered plant species belonging to 49 families and 84 genera, with 10 species in *Liliaceae*, seven species of both *Magnoliaceae* and *Ranunculaceae*, and three species of *Orchidadeae*, *Solanaceae*, *Theaceae* and *Pinaceae*. It has three species of Grade I national protected plants (*Taiwania flousiana*, *Davidia involucrate* and *Taxus yunnanensis*), 11 species of Grade II national protected plants (e.g. *Cephalotaxus lanceolata*), and 26 species of Grade III national protected plants (e.g. *Euptelea pleiospermum*) as well as some locally protected plants.

One hundred and thirty-nine (two-thirds) of the wild animal species found in the region are rare or endangered. Eighty species are nationally protected on China's Red List, and 63 species are internationally protected on IUCN's Red List (1996). The list of animals in the region accounts for half of the total of animals in the Hengduan Mountain system, and between one quarter and one-third of the total of animals in China (see Tables 2 and 3). Many rare and endemic plant and animal species – most famously the Yunnan Snub-nosed Monkey (*Rhinopithecus bieti*) – serve as representative species for habitats and vegetation types.

In the past, NW Yunnan's abundant natural forests were seen as a valuable resource with which to fuel economic growth, and by the late 1990s timber extraction was among the most important sources of villagers' income and local governments' tax revenue (Zhao et al. 2001). Following the disastrous flooding of the Yangtze River in 1998, natural forests have become increasingly valued by the government for watershed protection (Zhao et al. 2001). A ban on logging in all natural forest has had significant adverse impacts on rural livelihoods (*ibid.*). NW Yunnan has an extensive system of nature reserves, which aim to conserve biological diversity. The region is also heavily populated by peoples who, due to nature reserve regulations, are excluded from access to a variety of natural resources that are essential to their livelihoods and well-being. However, the local government hopes that the increasing tourism potentials will improve local livelihood.

To address the diversity, dynamics and complexity in NW Yunnan, an innovative approach to biodiversity conservation is required. As the first stage in building such an approach, the research reported in this paper attempts to understand the factors affecting biodiversity in NW Yunnan. In undertaking this research we aim to make the findings relevant to the formulation of policies and interventions that conserve biodiversity, while also supporting the sustainability of local livelihoods.

Research approach

Macro- and micro-level studies of human impacts on the environment each have their advantages and disadvantages (Marquette and Bilsborrow 1997). Here we are interested in the links between macro-level forces and micro-level decisions that influence biodiversity use and its representation in the landscape. Our research was

Table 2. Comparison of the species in northwest Yunnan, Yunnan, China and the World.

Taxonomic group	Northwest Yunnan	Yunnan	China	The World	NW Yunnan as % of China
Mammals	173	278	581	4170	29.8
Birds	417	793	1244	9198	33.5
Reptiles	59	141	376	6300	16.0
Amphibians	36	102	284	4184	12.7
Vascular plants	7000	16 000	34 000	275 000	20.6
Vegetation types	10 vegetation types and 98 formations	12 vegetation types and 169 formations	29 vegetation types and 560 formations	–	–

Source: Ji (1999).

Table 3. Endemic animal species in northwest Yunnan.

Animal group	Species	Endemic species	Percentage of species that are endemic
Mammals	173	81	46.82
Birds	417	22	5.27
Reptiles	59	27	45.76
Amphibians	36	25	69.44
Total	788	200	25.38

Source: Ji (1999).

based on a set of eight site-specific case studies, analyzed using a common framework in order to generate conclusions that were well-grounded in local realities and that were also of policy relevance.

The case studies were undertaken by multidisciplinary teams of social and natural scientists. Most of the community case studies used rapid community assessment methods in addition to botanical and ethnobotanical field research methods. The communities were selected to represent localities with different ecological systems, as well as different ethnic groups and livelihood systems (see Table 4). Two separate studies of forest fires and pests in the region were also undertaken.

In order to produce recommendations that can be generalized across the region while at the same time are grounded in local reality, we developed a simple framework[1] for categorizing the factors threatening biodiversity reported in the case studies. The framework consists of five different types of factors, which are defined in Figure 3 and described in Table 5.

We began the process of identifying factors that impact on biodiversity by looking at the human actions from the case studies that were reported to have impacts on biodiversity.[2] Based on their role in the causal chains reported in the case studies, factors that repeatedly occurred in many case studies were labeled and assigned to one or another type of factor. The quality of the case studies varied. Factors were only identified where sufficient supporting evidence was provided in the case study itself. In many cases, specific redressive actions or interventions were suggested in the case study reports. Overall recommendations were formulated on the basis of analysis of the recurrent, cross-cutting or underlying issues.

Analysis by drivers

Food production

Most food crops grown in NW Yunnan are produced for household consumption, either as food grain, conversion into alcohol or as livestock fodder. The contracting

[1] This framework benefited from a reading of an earlier draft of Geist and Lambin (2002).

[2] In a minority of cases, factors or causal relationships between factors were interpreted by the analysts on the basis of information contained in the case studies.

Table 4. Summary of survey sites.

Survey site	Nearby Nature Reserve	Main ethnic groups	Main factors impacting on biodiversity
Jiuhe Village, Jianchuan	Laojunshan	Bai	Forest fire, forest clearance for arable lands, NTFP collection
Tuomunan Village, Zhongdian	–	Tibetan	Grazing, house construction, fuel wood procurement
Shier Village, Deqin	Baima Xueshan	Lisu (80%), Tibetan (20%)	Construction timber, fuel wood and NTFP collection, forest clearance for arable land
Yeri Village, Zhongdian	Baima Xueshan	Tibetan	Construction timber, fuel wood and NTFP collection, grazing
Dimaluo Village, Gongshan	Nujiang	Nu (70%), Tibetan (20%), Lisu (10%)	Fuel wood, roof tile and NTFP collection
Bapo Village, Dulongjiang, Gongshan	Nujiang	Dulong	Road construction, NTFP collection
Shuanglawa Village, Gongshan	Nujiang	Nu (90%), Lisu (105)	Road construction, forest clearance for arable land
Zhulida Village, Gongshan	Nujiang	Nu (33%), Lisu (33%), Dulong (33%)	Fuel wood, roof tile and NTFP collection

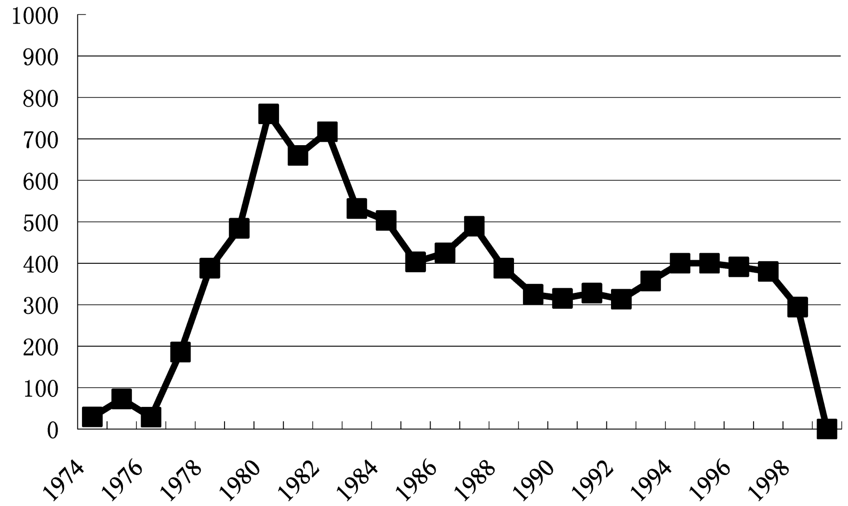

Figure 2. Timber logging extraction in Diqing Prefecture, NW Yunnan, 1974–1999 (thousand cubic meters). Source: Statistical Reports of Diqing Prefecture Forestry Bureau (1974–2000).

of land to households for cultivation, and increases in agricultural product prices in the 1980s significantly increased total grain output in NW Yunnan, yet in some areas food production per capita remains little changed (see Table 6). Poverty is still widespread throughout NW Yunnan. Almost one-third of the households in upland areas report insufficient food available for at least one-third of the year. For those households, food consumption needs must be met with cash income from other sources. Many of the common sources of cash income for poor farmers in upland areas have adverse impacts on biodiversity (e.g. NTFP collection, livestock grazing, timber felling).

Impacts of agricultural extensification

Swidden cultivation has been the main agricultural technique for centuries among many of the ethnic groups of NW Yunnan. Generally, swidden cultivation leads to the fragmentation of lower altitude forest. However, after a number of years fields are abandoned and the forest is left to regenerate. The regeneration is sometimes assisted by the planting of trees such as *Alnus nepalensis* (Yin 1994). In recent decades, however, conversion of forest ecosystems for cash crops (e.g. butter beans or medicinal plants) has become a major source of land transformation in many parts of the region. The clearing of new arable land replaces naturally occurring plant species with a few non-native crop species, multiple layers of monoculture. In most of the case studies, the expansion of the area of cultivated fields has meant the permanent replacement of (often secondary) forest, particularly those close to villages. In one case it impacted on grassland. In most areas of the region, the per capita area of permanent fields and application of modern inputs has increased, so rates of expansion have slowed in recent years.

Box 1: Types of factor involved in biodiversity impacts

1) Biodiversity impacts: Changes in ecotype, vegetation, animal or plant types and species observable over a relatively short period. Where quantifiable measures of change could not be obtained, we relied on villagers' perceptions of changes.

2) Drivers of impacts: Drivers are activities (mostly human activities, such as hunting wildlife and gathering Non-Timber Forest Products, logging operation) that directly affect the environment or specific components of biodiversity, and thus constitute direct drivers of change in biodiversity at the local level [cf Geist and Lambin (2002)].

3) Underlying factors: Underlying factors are causally related to drivers of biodiversity impacts. Although there are many reasons why specific activities or behaviours are undertaken(see Vayda 1983), some factors have a broader impact by motivating many individuals to engage in either particular activities or a range of activities. Thus, underlying factors operate at a larger scale than the household or even community. Many underlying factors operate over a longer period of time, and thus include longer-term trends (such as population growth and migration) .

4) Trigger factors: Triggers are causally related to drivers of impacts on biodiversity. Triggers are factors that operate over a specific period of time, and are often 'trigger events' that lead to other factors coming into operation. With the exception of natural disasters, trigger factors mostly do not operate directly on biodiversity, but 'trigger' other factors that lead to drivers, sometimes through complex causal chains (such as change of land tenure, building new road).

5) Contributing factors: Especially at the site-specific level, a complex array of biophysical, socio-economic and cultural factors may all have played some part in determining a particular outcome. Identifying which specific factor has played what role is a difficult task. We have attempted, when interpreting the individual case studies, to make a weak form of the *ceteris paribus* assumption. That is, all other things being equal, changes in this factor would lead to changes in levels of impact on biodiversity. Thus, contributing factors include predisposing factors or initial conditions that are judged to have played a causal role in the process that led to an impact on biodiversity. Contributing factors do not include concomitant but non-causative factors.

Figure 3. Types of factors involved in biodiversity impacts (Vayda 1983).

Amounts of expansion varied widely among the case studies. The amount of area cleared for arable land appears to be related to the pressure behind the expansion. Where population growth and low levels of grain output are the main pressures, expansion has been gradual over decades. In some cases sudden triggers, such as road construction and naturally induced landslides, have led to rapid expansion of new arable fields. One case, in which stable fields were destroyed by landslides from road construction, found that while the area of new fields cleared was greater than the area of fields lost, the total output of the newly expanded area was lower than the output of the area lost. The difference was made up by activities that impact on other natural resources, such as logging and NTFP collection for sale.

Table 5. Factors causing negative impacts on biodiversity in NW Yunnan.

Type of factor	Factor	Common examples
Drivers	Food production	Slash-and-burn
		Hillside agriculture
		Application of modern inputs
	Fuel wood collection	Fuel wood collection for heating
		Fuel wood collection for food processing
	Timber procurement	Procurement for house construction
		Commercial logging
	NTFP collection	Hunting
		Medicinal plant collection
		Mushroom collection
	Livestock grazing	Grazing in forests
		Grazing on alpine meadows
Underlying factors	Demographic changes	Natural growth
		Migration
		Family partition
	Market demand and changes in market prices	Unstable procurement prices for NTFPs
	Market regulation mechanisms	Open access tenure systems
		Free markets
	Land and resource tenure policy and practices	Allocation of land use rights to households in the 1980s
	Development policies and interventions	Infrastructure development
		State subsidies
		Extension of modern agricultural technologies
Triggers	Political movements	Great Leap Forward (late 1950s)
	Tenure policy reform	Forest land allocation (ca. 1982)
	Infrastructure development	Road construction
	Forest fire and pests	Insect infestations
		Forest fire
Contributing factors	Technology levels and dissemination of new technologies	
	Income poverty	
	Resource and tenure policies	
	Household structure	
	Altitude and climate	
	Market prices	
	Population migration	

Table 6. Food production in NW Yunnan (kg per capita).

	1978	1980	1985	1989	1994	1997	1998
Diqing	358.35	350.28	346.31	344.54	358.15	384.76	384.46
Nujiang	263.48	253.12	242.14	263.04	286.03	324.07	337.26
Dali	304.39	275.80	254.98	240.07	332.72	377.88	400.04
Lijiang	360.79	352.91	294.12	332.66	303.28	368.86	356.48

Source: Yunnan Statistical Yearbooks (1978–1999).

Agricultural intensification
In many areas throughout NW Yunnan, terraced fields were constructed in the 1960s, using labour mobilized by the collectives. Since the 1980s, fertilizer and plastic sheeting have been widely adopted to increase output. The result has been a reduction in length of fallow, increased use of chemical fertilizers and wider adoption of hybrid seed varieties in both permanent and swidden fields. Several case studies suggest that agricultural intensification has noticeable impacts on agro-biodiversity and soil fertility. With intensification of agriculture, the government has introduced policies to encourage conversion of sloping farming land to forest or grassland (Zhao et al. 2001). However, the case studies found that the quality of forest plantations was poor, mainly consisting of exotic mono-species.

Contributing factors
- *Technology*: household access to modern inputs such as chemical fertilizer and high yielding crop varieties can increase the unit area output of fields and reduce the total area of forest cleared for arable land.
- *Low cash incomes*: cash income poverty prevents the wide scale adoption of these inputs.
- *Policies*: in some cases, recent bans on the burning of new swidden fields were found to increase the total area under cultivation, since the output of older swidden fields is lower than that of newly burnt fields. In the past, clear-felling of forest to create cultivable fields has been promoted by local government agricultural development policies and by the instability of national land tenure policies.

Fuelwood collection

Levels of utilization and impact
There is great variation in fuelwood consumption levels at different elevations and in different cultural communities within the region. The case studies found that each household consumes in the range of 10–30 m^3 each year. In most of the communities studied, the collection of fuel wood is recognized both by farmers and forestry agencies as one of the major factors in forest depletion. For example, in Diqing Prefecture a total of 600 000 m^3 of fuel wood is collected each year, mainly from oak forests. In several sites villagers reported that collection of fuel wood is occupying increasing amounts of labor time.

Contributing factors

- *Fireplace technology*: in Nujiang Prefecture sites, all are open hearths with iron tripods, while in Tibetan areas a special kind of iron hearth with better heat-retention properties is used.
- *Household structure*: at most sites the prevailing custom for newly married couples is to build their own house, thus increasing the number of hearths and demand for fuel wood. In the Tibetan communities surveyed there has been a gradual trend towards smaller households.
- *Uses of fire*: apart from daily uses such as cooking and heating, the processing of products, such as making of wine, and processing oil or milk products, constitutes demand for fire and firewood. Thus, levels depend on local consumption preferences.
- *Altitude and climate*: fuel wood consumption in the highlands (> 2500 m a.s.l.) is around double that in the midlands and triple that in lowland hot valleys.
- *Forest tenure*: in some sites the lack of clear and enforceable tenure rights to different parts of the forest surrounding villages means that fuel wood is collected in an unplanned way, and collection/utilization is unrelated to planting of fuel wood forests. Only one site report mentioned that villagers actively plant fuel wood trees.

Timber procurement

From the 1950s until the late 1990s, the abundant forests of NW Yunnan were seen as a valuable resource for economic growth. State logging companies which often employed local villagers were set up, often also employing local villagers. Many local communities relied on logging and related activities (such as transport and restaurants) for their livelihoods. In 1999, a logging ban was implemented throughout NW Yunnan (Zhao et al. 2001). This policy applies strict quotas on the volume of timber that can be extracted in each area. Following the ban, housing remains the main source of demand for timber.

Impact of logging

The region is especially rich in conifer forests. The most important commercial timber species in the area are various firs (e.g. *Abies delavayi*), spruces (e.g. *Picea likiangensis*), and pine (*Pinus yunnanensis, P. desnata, P. aramandii*). Other species present include juniper, scrub oak, birch, maple, and poplar. Large scale logging operations initiated in the mid-1970s have resulted in the loss of habitats for wildlife and other endangered species, soil erosion and landslides in the region. Mono-culture forest plantation by the state, agricultural cash crop plantation by farmers, and conversion to pasture land by pastoralists after logging suppress the natural regeneration of forests, further contributing to biodiversity loss. A total area of 7595 km^2 (mainly on steep slopes after logging followed by farming) in Diqing Prefecture is subject to soil erosion. In the 1960s, sediment was 0.568 kg/m^3 in the Jinsha River (the upstream of the Yangzi River) and 1.19 kg/m^3 in the Lancang (Mekong) River, but these values increased to 0.61 and 1.24 kg/m^3, respectively in

the 1980s, bringing 1.3 billion tons of soil into the Jinsha River alone (Zhao et al. 2001).

Logging is responsible for widespread deforestation in NW Yunnan. The amounts of timber extracted in NW Yunnan have varied greatly year by year (see Figure 2 for data on Diqing Prefecture). The data suggest that in general, the amount of timber extracted through commercial logging has been less than that used for local house construction and fuel wood purposes. Impacts, however, may differ. Commercial logging causes clear-felling of total forests, while extraction for household use, being restricted by the need for timber of certain qualities and by limited access, changes the density and structure of forest in patches.

Impact of housing demand

Currently, quotas are issued for household procurement of timber. For example, in Diqing Prefecture each year 1 household per 30 households is allocated a quota for constructing a new house. The quota is 120 m^3 per house in the highlands (though in fact, on average one house consumes a total of 150 m^3, and exceptionally as much as 300 m^3), 70 m^3 in the midlands, and 45 m^3 in the lowlands. Thus in 1 year, Diqing Prefecture approves a total of 960 000 m^3 of timber for local consumption. In contrast, the timber used for constructing a new house in Nujiang Prefecture is much less: 11 m^3 for a Nu or Tibetan log house, or 22 m^3 of pine for a traditional Lisu timber plank house. In areas inhabited by the Nu people it is common for many families to have two separate houses. The roofing, which needs to be changed every 10–15 years, consumes a lot of good quality *Abies* or *Picea* trees. Suitable timber for roof tiles was reported by villagers to be hard to find in all the survey sites in Nujiang Prefecture.

At many sites, villagers report that construction materials are increasingly hard to find. Mostly, this is the result of long-term pressure on construction timber resources. But in some cases, the current scarcity is due to previous clear-felling for commercial logging, often by outsiders. Construction timber procurement by villagers rarely, if ever, involves clear-felling, since many trees are not suitable for construction use.

Contributing factors

- *Traditional housing design*: this is the most direct determinant of levels of timber utilization. Housing design (e.g. in Tibetan areas) and choice of construction material (e.g. in Lisu areas) are associated with important cultural beliefs and practices.
- *Household structure*: neolocal marriage and a gradual trend towards smaller households in Tibetan areas affect demand for housing.
- *Policy*: previous policy encouraged commercial logging, but in 1999 the logging ban greatly restricted the amount of timber felled for commercial purposes. Villagers' own housing needs remain a pressure on already depleted timber resources.
- *Tenure security*: the historical disputes of borders between different communities have increased and boundaries between state and collective forest have deterio-

rated due to increased illegal felling of timber in the past years, as well as increasing marketing value of matsutaki mushroom.

NTFP collection

Levels of utilization
All the sites reported varying levels of NTFP collection and hunting. Collection of plant resources is mostly for sale. It was not possible to assess the impacts of NTFP collection in relation to total available resources. However, NTFPs constituted significant proportions of household cash incomes (often between 25 and 80% of household cash income). Several case studies reported over-collection as evidenced by disappearance of species. Over-collection was uniformly related to changes in market demand and changes in market or procurement prices. It is often also associated with outsiders exploiting local resources either as collectors or procurers. Some case studies reported that NTFP collection has negative impacts on forest or grassland ecology (e.g. in alpine meadows), while others found little disturbance of forest ecology despite large-scale collection of NTFPs.

Bans on hunting in nature reserves appear overall to be effective in limiting the amounts hunted, although occasional hunting by both villagers and local officials is still common. In some areas hunting is still a common activity. While it is difficult to assess actual impacts, it appears that large mammalian species are rare in most places. Following the legal restrictions on hunting in nature reserves and on sale of animal products in restaurants, market demand accounts for only a small proportion of hunting. The establishment of nature reserves has, in some cases, led to an increase in the number of wild animals, which conflicts with villagers' production concerns.

Contributing factors
- *Market demand and prices*: collection of wild fungi and medicinal plants is highly responsive to market or government procurement prices.
- *Planting and harvesting technologies*: for species that can be artificially planted, levels of impact do not constitute a threat. In some cases harvesting techniques damage the reproductive capacities of species and interfere with the local ecology.
- *Migration*: market information is primarily supplied by outsiders who also engage in collection or procurement of local produce. All the cases of over-collection reported in the case studies occurred where outsiders are heavily engaged in collection or primary procurement.
- *Legal framework*: large-scale hunting by villagers has been contained by legal bans on hunting in nature reserves. However, in some cases government officials and soldiers do not always observe the laws. In one site that borders on Myanmar, villagers resent the fact that the hunting of species that are protected in China is legal in Myanmar. Because the very same animals can cross the border, it is difficult to enforce wild animal protection among villagers. In areas bordering nature reserves, attacks by wild animals on crops and livestock are either

compensated at very low levels or not at all, making it difficult to prevent villagers from protecting their assets.

Livestock grazing

Impacts of grazing

The villages surveyed vary greatly in the extent to which they engage in livestock raising. Those where livestock numbers are small often lack access to grazing land, either because of the lack of suitable resources in the area or because of legal restrictions on grazing in nature reserves. Unfavorable market prices also tend to limit the number of livestock raised. In villages where livestock numbers are significant, livestock products have traditionally been the main industry, and alpine pastures are available (e.g. in Nu and Tibetan areas).

Two types of rangeland are used: grazing within forest and grassland grazing. Where grazing involves forest resources, several case studies report severe impacts on the quality and composition of forest undergrowth, and on forest regeneration, particularly the regeneration taking place close to residential areas. Deterioration of alpine pasture quality is common. One study found that between 40 and 100% of pasture was covered with inedible plant species. Problems of over-concentrated grazing are more common than over-grazing.

Contributing factors

- *Market prices*: where livestock are raised for sale, livestock numbers and hence the impact of grazing are very responsive to livestock prices, while in other places they are not responsive at all because livestock are raised for other products.
- *Policy*: in areas with a long history of livestock raising (especially in Tibetan areas) traditional practices to improve the species composition of alpine pastures are effective. However, restrictions on the burning of pastures and on access to rangeland within nature reserves have led to the deterioration of rangeland quality and area. This places greater pressure on other fodder resources.

Analysis by underlying factors

Demographic changes

The population of Yunnan grew from approximately 10 million in the early 1900s to about 20 million in the early 1950s. Within the last half century the population has again doubled to over 42 million in 1999. The vast majority of the population live in rural areas (Yunnan Statistics Bureau 2000). Population growth contributes to increasing consumption, increases in levels of production activity and thus to conversion of land use. In general, population growth in ethnic minority areas has been higher in the highlands than in the lowlands.

Table 7. Increases in human and livestock populations in NW Yunnan (thousands).

		1978	1980	1985	1989	1994	1997	1998
Diqing	Human	260	269	290	308	323	330	330
	Livestock				238	256	277	283
Nujiang	Human	338	351	396	425	450	458	459
	Livestock				132	148	159	165
Dali	Human	2603	2660	2813	2990	3133	3209	3235
	Livestock				791	858	941	956
Lijiang	Human	874	893	945	1001	1050	1078	1086
	Livestock				375	401	430	439

Source: Yunnan Statistical Yearbooks (1979–1999).

The case studies at the community level showed that population growth always acts on the environment through other specific drivers, such as construction timber procurement or clearance of land for food production. Consumption patterns differ between cultural communities, hence impacts on biodiversity differ. For example, cultural practices regarding choice of marriage partner and post-marriage residence are important variables in determining levels of construction timber and fuel wood collection. Migration into and within the region has been significant, and is a factor underlying incidences of major impacts on biodiversity, such as over-collection of NTFPs.

A variety of contributing factors play important roles in determining the biodiversity impacts of population change. These variables include technology, prices, policies, and cultural preferences. Aside from current levels of utilization, past histories of resource use are important to determine whether current levels of consumption exceed the reproductive thresholds of local biological resources. In general, it appears that these intervening variables are more likely to bring about thresholds in resource use than population growth on its own. Specific cases included the recent introduction of a mechanical saw to the Dulongjiang watershed, past clear-felling for commercial logging, policy-driven clear-felling of forest to plant medicinal plants, and the impacts of road construction.

Livestock populations have also risen steadily (Table 7). More and more farmers in the uplands rely on livestock for cash income, social security, as a store of value for future expenditures, and to pay for marriages and schooling. Most farmers said that livestock raising provides their main income generation potential, since incomes from logging decreased over the last 3 years.

Market prices and regulation

Market demand has a variety of impacts on biodiversity. Changes in market prices can have positive impacts on biodiversity. A sudden drop in the price for sheep in one county led villagers to decrease the numbers of sheep dramatically, with benefits for forest regeneration. However, especially in Tibetan areas of NW Yunnan, livestock numbers are unresponsive to changes in animal prices, since they are

raised for products other than meat. Levels of collection of wild fungi and medicinal plants are highly responsive to changes in market prices. Cases of over-collection have been found at many of the study sites and are mostly associated with sudden rises in market (or government procurement) prices.

One reason for this is the lack of regulatory institutions for NTFP markets. The NTFP market is mostly a classic free market where producers only face information and cost constraints. Price information is mostly brought to villages by outside collectors or purchasers. Collectors and purchasers from outside are unconcerned about the sustainability of harvesting. NTFP collection at many sites has produced a range of problems, including resource tenure conflicts, conflicts over the equity of benefit distribution, and depletion of resources due to over-collection or improper collection techniques. In many sites, NTFPs are collected from common property or open access resources (e.g. nature reserves) where there is no representative agency to effectively control levels of use or collection practices. Many NTFPs are liable to an agricultural product tax, but enforcement is difficult. Only one case reported a successful attempt to regulate collection, in which outsider collectors were charged fees by the village administration.

Fortunately, strict legal bans on hunting and the sale or trade of protected species seem to have gone a long way to reducing the effective demand for many wild animal products. However, the long international border between China and Myanmar makes enforcement difficult. The strictly enforced ban on logging has reduced timber felling and sales dramatically. National demand has been transferred to other countries in southeast Asia and elsewhere (Pearce 2001).

Government policies

Resource tenure policies

Tenure enforcement: land and forest user rights in many places covered in these case studies are ill-defined or difficult to enforce. For example, Heyuan village lies at the adjoining point of three prefectures and villagers from the other prefectures illegally fell timber from Heyuan's forests. Disputes crossing administrative boundaries are notoriously difficult to resolve. Disputes over grazing rights between villages in Nujiang and Diqing prefectures have continued for decades. In 2000, the alpine pasture was adjudicated by a provincial agency to belong to Diqing, but villagers in Nujiang continue to contest the decision. Fearing that a conflict may erupt, villagers camp close together in the summer grazing season, which results in rapid degradation of pasture in those areas. In both cases, difficulties in enforcing tenure rights have adverse impacts on biodiversity. Ill-defined tenure rights over forest adjoining or in nature reserves also make effective forest management impossible.

Tenure change: sudden changes in tenure policy have historically been related to increases in the use of forest resources and even clear-felling. The introduction of the household responsibility system and forestland allocation policies in the early 1980s are two examples of forest tenure policy changes which in many sites led to excessive felling of timber, from which the forest has still not recovered. The most recent major policy-induced change in tenure rights is the logging ban. Under the

policy villagers retain their rights to manage forests, but their rights to disposal are withdrawn. The difference between this and earlier changes in tenure rights is that the logging ban also restricts the effective market demand for timber through limiting quotas for the sale of timber.

Establishment of nature reserves: a very special case of changes in tenure rights is the establishment of nature reserves. Seven of the case study sites are located next to or in the core areas of nature reserves. The establishment of nature reserves has been widely associated with loss of legal access to productive resources, such as swidden land, pasture, construction timber, and NTFPs. One response by local communities has been the continued illegal use of resources. This is often made easier by the establishment of nature reserves, which makes the nature reserve an unmanaged open-access area. Over-collection of NTFPs becomes exceedingly difficult to control in this situation, and the enforcement of illegal logging and hunting is costly and often ineffective. A second response has been to intensify utilization of substitute resources. For example, with the establishment of Baima Xueshan nature reserve, Yeri Village was unable to continue managing the species composition of pasture in the nature reserve through controlled burning. The result has been a decline in the quality of pasture, which puts greater pressure on other rangeland resources such as forest undergrowth. With the loss of access to NTFPs and other resources in the nature reserves, villagers have to rely much more heavily on other resources for cash income sources, sometimes with negative impacts on biodiversity.

Development policies

Production policies: historically, local government development policies have often focused on the exploitation of natural resources. This is most clearly the case with commercial logging, which was a main source of fiscal revenue for many counties in NW Yunnan until the logging ban. Other cases include the promotion of medicinal plant cultivation, which often involved the clear-felling of forest to create new fields. Many of the pressures on timber and other forest resources now faced by villagers are the legacy of these earlier development policies. Infrastructure development is a special case of local development policy which also impacts on biodiversity.

Infrastructure development: three village case studies reported adverse impacts on biodiversity due to road construction. Some of these impacts have been dramatic. In two cases the main direct impact was on arable land. This can induce a sequence of indirect impacts, such as clearing of new swidden land, relocation of housing and increased construction timber demand. The construction of a highway to Dulongjiang led to the clear-felling of over 1300 ha of primary forest and the disruption of the migration route of protected animals (e.g. *Bos frontalis*), thus putting them at greater risk. Following the completion of the highway, the increased supply of luxury consumer products stimulated the demand of local people for cash income, and thus facilitated the access of outsider purchasing agents to local NTFPs, which are now in danger of being over-collected.

State subsidies: state subsidies are one mechanism used to implement development policies. They contribute greatly to current pressures on ecosystems by encouraging activities such as over-collection of forest products, as exemplified in the collection to near exhaustion of taxol (*Taxus yunnanensis*) tree bark. Local loans or subsidies to support township enterprises for biological resource development have damaged local ecosystems, through land conversion for monoculture plantation, depletion of natural resources in the forest ecosystems and pollution of highland lakes.

Analysis by trigger

The major triggers of impacts on biodiversity discovered through the case studies are the Great Leap Forward of the late 1950s and the allocation of forest rights to village collectives and households in the early 1980s. Due to their origin in national policies, these two historical trigger events have had impacts on land cover and natural ecosystems in almost all communities in NW Yunnan. Infrastructure development and natural disasters are also factors that can trigger a series of major impacts on biodiversity at the individual or multi-site level.

The Great Leap Forward

The Great Leap Forward (ca. 1959–1960) was a political movement arising from Mao Zedong's desire to 'catch up with Britain and overtake America'. During this period, the central government called on all communities to make China self-sufficient in steel. Forests were cut and the wood was burned to fire local furnaces, although much of what was smelted was of little use value (Shapiro 2001). An emphasis on local self-sufficiency was also stressed at various times during the Cultural Revolution (1966–1976). During this period forest clearance was often to clear arable fields or plant cash crops. For example, in one site, large areas of forest were cleared for medicinal plant cultivation in the late 1950s and early 1960s. Markets for such products soon failed and some four decades later, villagers are left with large areas of fern forest (an early stage of forest regeneration) and a thick cover of medicinal product trees with little value.

Forestland allocation in the 1980s

Frequent shifting tenure of forestland is another trigger for deforestation. During 1978–1983, farmland was contracted to individual households to cultivate. However, ownership of forestland was retained by the state. This often caused conflicts between government and village collectives or individuals. In order to stabilize forestland and swidden fields, forest tenure was redefined to include state forest, collective (village) forest and freehold (household) forest. Both freehold plots and collectively held forests could be leased to individual households. Dense forest is often

held by the government as state forest or as nature reserve. Collective forest could be reallocated to individual farmers for management. Every household received a piece of forestland for fuel wood collection and tree plantation. Unsure of the duration of the new policy, in many villages the newly allocated forest was rapidly clear-cut by villagers.

Infrastructure development

Road construction in the region lacks environmental impact assessment, and the government agency responsible for environmental assessment is urban-focused. For instance, a new road constructed to Dulongjiang with a distance of 80 km has had great impacts on alpine forest ecosystems, the migratory routes of wild oxen and local livelihoods. Many paddy fields and swidden fields have been damaged by landslides and mud-flows during and after construction.

Forest fire and pests

Yunnan has the highest frequency of forest fires in all of China, averaging 2725 incidences per year. On average, forest fires burn 138 259 ha forest (or 40 000 m^3) each year in Yunnan. Between 1951 and 1998, Yunnan's forest fires accounted for 19.2% of all those reported in China. Within Yunnan, between 1980 and 1990 the area affected by forest fires in NW Yunnan accounted for just over 50% of total burned area and 72% of the timber loss to fire in the whole province. In 1999, major forest fires occurred in both the Gaoligongshan and Yulong Snow Mountain Nature Reserves, the former burning over 3887 ha of forest with a loss of 210 000 m^3 of timber. The dangerous period for forest fire lasts for 6 months each year from December to May. Data on forest fires for the four prefectures between 1985 and 1995 show that 99.8% of all forest fires were due to human factors, and only 0.2% naturally induced. Among human induced fires, 42.7% were due to the use of fire in production (e.g. clearing swidden fields, burning of paddy bunds or pasture), and 43% to non-productive uses of fire (including cigarettes, fires for heating or cooking, children playing with fire, and burning incense for graves). The sources of 10% of fires are unclear. Thus, the most common causes of fire are its uses in agricultural production and other outdoor pursuits.

Pests have caused the largest forest loss in the history in Zhongdian county in NW Yunnan. A total of more than 20 000 ha of native *Abies* forest has been eaten by a type of caterpillar (*Dendrolimus angulata*) since 1986. The scale of this loss is equivalent to the impact of 25 years of logging in the local area. Mono-cultural plantation makes forest more vulnerable to fire, pests and diseases.

Conclusions

This study shows that we should pay more attention to the large uncertainties of biodiversity and livelihoods in the mountain region of Yunnan, which are caused by the most powerful contemporary driving forces and its sequences of impacts.

Main findings

The research reported in this paper was based on a set of detailed micro-studies, analyzed using a common framework that focuses on the role of different factors in causal chains that lead to biodiversity loss. Biodiversity loss in the region is mainly driven by land use and land cover change. Logging followed by mono-culture forest plantation, cash crop plantation, and livestock grazing have contributed significantly to biodiversity loss in the past. Market driven biodiversity loss is a major threat at present, especially for NTFPs.

Table 5 summarizes the main factors that were found to impact on biodiversity, and Table 8 lists the distribution of common factors over the typical vertical distribution of vegetation types found in the region. The cases reviewed indicated that processes causing biodiversity impacts could not be understood separately from the specific human-environment conditions (both biophysical and socio-cultural factors) under which the drivers of change operate. Micro-case studies can contribute to our understanding of the more general processes of biodiversity change by illuminating the ways in which people and the environment interact under the influence of specific trigger events and within a specific habitat. Better understanding of these processes requires more collaboration between the natural and social sciences.

Implications for redressive action

The combination of case studies with a common analytical framework enables implications for redressive actions to be drawn at several levels. Some of the case study reports contained recommendations for redressive actions made by the field researcher or by the community members themselves. Recurring issues and common recommendations were then categorized based on the main drivers they addressed (see Table 9). Finally, a set of cross-cutting themes of relevance to the policy-making process was identified.

Current events in northwest Yunnan are indicative of what is occurring in many global biodiversity hotspots. The formulation of appropriate interventions in mountain regions such as NW Yunnan requires an integrated policy strategy which links culture, nature and livelihoods as a holistic system. In addition to a focus on biodiversity conservation, it is important that attention is given to creating policies that are supportive of equitable and sustainable livelihoods for indigenous communities. Essential elements of such policies are that they provide local farmers and communities with secure prior rights to access to decide over and benefit from sustainable resource use. Equitable marketing access, which recognizes both collective and individual intellectual property rights of local communities, is necessary

Table 8. Vegetation types, conservation significance and threat factors in NW Yunnan.

Vegetation type	Representative species	Conservation value	Key threat factors
Rock, snow, ice and glacier >4800 m		Ecological services	(1) Increasing tourists by cable car (2) Global warming
Screes >4000–4800 m	*Saussurea* spp., *Fritillaria delavayi, Meconopsis*	Many endemic/rare species, easily damaged	Over-collecting of medicinal plants
Alpine heath and meadow 3800–4800 m	*Rhododendron* spp. *Salix* spp. *Caragana* spp. *Arenaria polytrichoides*	Many endemic/rare species, easily damaged	(1) Over-grazing and over-concentration of grazing (2) Rutting by pigs
Alpine conifer 3000–3800 m	*Picea* spp. *Abies* spp. *Quercus* spp.	Growth of these trees is very slow, regeneration very slow once damaged	(1) Roof tile material procurement (2) Livestock grazing in forest understorey (minor impact)
Deciduous forest 2600–3900 m	*Betula* spp. *Larix* spp. *Populus* spp.	Little known	(1) Timber used for small utensils (2) Timber used for building shepherds' huts for seasonal grazing (3) Major impact of grazing on forest understorey
Oak forest (on north-facing slopes) 3000–4000 m	*Quercus* spp.	These oaks are special due to high elevation and provide key habitat for various types of fungi	Collecting oaks for livestock bedding (20 ton/year in some Tibetan villages)
Pine 2500–3500 m	*Pinus yunnanensis* *Pinus densata*	Ecological services	(1) Timber extraction (2) Forest fire and pest

Table 8. Continued.

Vegetation type	Representative species	Conservation value	Key threat factors
Mixed forest (pine with others)	*Taxus yunnanensis*, *Psuedotsuga forrestii*, indicating a belt of endangered plant species	Extractive collection of taxus bark for marketing	(1) Timber and fuel wood extraction (2) Compost collection (3) Over-collection of NTFPs
Savannah 2000–2800 m	*Heteropogon contortus, Terminthia paniculata*, Bauhinia spp. *Vitex* spp. *Sophora* spp.	Once damaged, hard to regenerate, particularly given dry conditions at lower elevations	(1) Collecting stone and sand for infrastructure construction (2) Fuel wood collection (3) Conversion to farmland
Riparian (evergreen, broadleaf and cedar) <2800 m	*Alnus nepalensis*	Regeneration is limited once disturbed	(1) Expansion of cultivated fields (2) Collection of construction material (3) Fuel wood collection (4) Collection of leaves for incense

Table 9. Summary of implications for redressive actions.

Driver	Possible redressive actions
Food production	– Technology extension and financing adoption of modern inputs (e.g. through micro-credit) – Development of agro-forestry options through participatory technology development processes, especially on converted sloped farmland plots
Fuel wood collection	– Alternative energy technologies (e.g. biogas, fuel saving stoves) – Promotion of fuel wood forest plots
Timber use	– Alternative materials for housing, cooking and heating – Vernacular geo-architecture designs based on traditional houses, using alternative materials: in some cases, alternative materials can be provided (such as slate tile roofing in Nujiang, and shell stone in Deqing). However, in some cases (e.g. Tibetan areas), redesign of housing must take account of cultural beliefs in order to be accepted by inhabitants – More efficient use of log and timber: more than 75% of the timber is wasted when villagers cut (*Abies*) trees for roofing tiles – More careful monitoring of timber quotas for local use – Continued enforcement of the logging ban to control commercial logging impacts
NTFP collection and hunting	– Market regulation – Compensation for wild animal attacks – Public education on protected species – International and regional coordination of conservation and management efforts
Livestock grazing	– Identification of suitable fodder species – Establishment of local pasture management institutions

for promoting sustainable harvest of local biological products. Environmental payment for ecosystem services of mountain ecosystems is another mechanism for benefit-sharing to the relevant communities, which promotes awareness of laws that affect resource use and trade; and increased local participation in planning of development and conservation initiatives.

Acknowledgements

The field research on which this paper is based was supported by the joint Nature Conservancy – Yunnan Planning Commission Yunnan Great Rivers Project, and further by the ADB-GEF field assessment and the Knowledge Innovation Program of the Chinese Academy of Sciences (Project grant no. KSCX2-1-09-06). The field studies were completed by Dr Wang Yuhua, Dr Luo Peng, Yang Xuefei, Xie Hongyan and Yang Zhiwei of the Kunming Institute of Botany, Zhang Jingfeng of Yunnan Academy of Forestry, Song Yuan and Luo Rongfen of Yunnan Academy of Social Sciences, and Wu Deyou of Southwest Forestry College. We also thank Barney Long for helpful comments on an earlier draft.

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